STONE & WEBSTER ENGINEERING CORPORATION

CHERRY HILL OPERATIONS CENTER
3 EXECUTIVE CAMPUS, P.O. BOX 5200
CHERRY HILL, NEW JERSEY 08034
TWX 710-892-0147
710-892-0148

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Mr. J. E. Booker
Manager - River Bend Project
Gulf States Utilities Company
P.O. Box 2951
Beaumont, TX 77704

January 14, 1980
J.O. No. 12210
RBS-4612
Response Not Required

Dear Mr. Booker:

FILE NO. G9.25.1.1
CODE OF FEDERAL REGULATIONS
REPORTABLE DEFICIENCY - 10CFR50.55(e)
RIVER BEND STATION - UNIT 1

References:
1. S&W Letter No. RBS-4466 dated November 19, 1979
2. Graver report dated December 6, 1979 (enclosed)
3. S&W report dated January 1980 (enclosed)

As a follow-up to your report to the commission on the containment corner junction weld (T-joint) under 10CFR50.55(e) requirements, we are providing our findings of the cause and corrective action to resolve the deficiencies. As used in this letter and the enclosed reports, the term "weld defect" or "defect" is used as defined in the American Welding Society's document AWS.A3.0-76, Welding Terms and Definitions.

The investigations by Graver and S&W, identified in Reference 1, have been completed. The following is a summary of those investigations:

Graver's Investigation (See Enclosure I)

Graver's investigations centered on the cracking being caused by equipment and/or procedure. They proceeded to create conditions they felt were the cause of the cracking present during production welding. These conditions were to modify the various parameters which could have caused the weld defects. The evaluated parameters were:

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a. The effects of the various hook-up connections possible with the DART 2108 dual head submerged arc welding equipment

b. Varying the number of shielded metal arc weld root passes

c. Changing the submerged-arc welding electrode flux combination

d. Varying the current and/or voltage

e. Changing the preheat, interpass, and post-heat temperatures.

S&W Investigation (See Enclosure II)

S&W's investigations were based on a metallurgical approach to determine the cause and corrective action for the weld defects. The metallurgical investigation was completed in accordance with the requirements of E&DCR No. P-M-(G)-1046.

In addition, S&W has investigated to determine if weld deficiencies exist in locations other than the root area. This was accomplished by grinding into the Unit I assemblies at the River Bend jobsite. The investigation showed that the indications of cracks were, in fact, either slag inclusions or erroneous interpretations of UT signals. There were no cracks in the weld other than in the root area.

Conclusion of S&W/Graver Investigation

S&W's report (Enclosure II) has determined that the cause of the cracking was undesirable weld nugget or bead shape deposited at the root. If the cracks are removed, the remaining weld material is metallurgically acceptable. The results were confirmed by Figures 9 and 10 of the report which show the open crack surface having a globular and not a fibrous structure which confirms a welding-related shrinkage solidification crack. A more complete summary of the cause can be found under the "Discussion, Conclusion, and Recommendation" section of Enclosure II, pages 3 and 4.

The actual welding technique that was used did not adversely affect the metallurgy to impair the toughness of the weld or the heat affected zone. The impact tests indicate adequate toughness. The tests were performed at $0^{\circ}F$ and $40^{\circ}F$. However, the tests at $40^{\circ}F$ are the ones relevant to our discussions, as they meet the ASME III Class MC code requirements for the lowest service temperature of approximately $70^{\circ}F$.

The specification requirement for the base material to qualify for impact strength at $0^{\circ}F$ is conservative compared to actual service conditions.

In their investigation, Graver has come to the same conclusion as S&W for the cause of the problem (see pages 17 and 18, Section 2.4 of Enclosure I). To preclude the problem from recurring, the most effective method to accomplish proper bead shape/nugget would be to redefine the weld electrode position and the number of shielded metal arc weld root passes.

Safety Implications

The containment is a safety-related structure and is described in Section 6.2.1 of the RBS PSAR. The function of the containment is to act as an essentially leaktight structure and limit the release of fission products in the event of a postulated design basis accident. If the weld defects identified in this report were to have remained undetected, the integrity of the containment vessel could have been jeopardized in the event of a design basis accident. Therefore, we have concluded that the weld deficiencies, if they had remained uncorrected, could have adversely affected the safety of operation of the nuclear power plant.

Corrective Action

During the evaluation process for the cause, a more refined UT technique was used to evaluate the root zone area. S&W recommends a sample retesting of two Unit I assemblies using a 60° dual transducer search. If the results reflect a rejection of greater than 50 percent, S&W recommends removing the entire weld which includes the defective root zone from one side only. For areas having less than 50 percent rejection, the unacceptable ultrasonic indications will be removed and replaced with sound metal. All resultant cavity areas will be rewelded to restore the containment corner junction welds to the originally specified ASME III, Class MC code requirements. Detailed work procedures will be developed by Graver and approved by S&W prior to rework. The repair welding will be done onsite using manual and semi-automatic procedures.

Should you need further clarification of the enclosed reports, please contact us.

Very truly yours,

J. A. Kirkebo
Project Engineer

Enclosures

DH:SLP

Enclosure I is for P.P.F. File.

RBS-4612

ENCLOSURE I

GRAVER ENERGY SYSTEMS, INC 029816

2200:4627-2
RMS:as
1979 DEC 11 PM 4:23

December 6, 1979

Project Engineer, J.O. Nos. 12210 (Unit 1), 12330 (Unit 2)
Attention: Lead Mechanics Engineer
Stone & Webster Engineering Corporation
3 Executive Campus, P.O. Box 5200
Cherry Hill, NJ 08034

SUBJECT: Contract Number RBS-219.710-C056
Containment Shell
Reactor Containment Vessel
River Bend Station - Units 1 and 2
Gulf States Utilities Company

Gentlemen:

Attached is the summary status report entitled, "Cause-and-Corrective Action Analysis Concerning Sub-Surface Defects Found in River Bend Corner Junction Tee Welds" dated December 4, 1979.

This report is the result of findings as reflected in the title of the report and is forwarded for your information.

Very truly yours,

GRAVER ENERGY SYSTEMS, INC.

R. M. Stanborough
Contracts Manager

Attachment

cc: Project Engineer, J.O. Nos. 12210 & 12330 (S&W - CH)
Contracts Manager (S&W - Site)
C. G. White (S&W - CH)
Manager, Procurement Quality Control Div. (S&W - Bos) (3)
Gulf States Utilities Co. (4)

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JAN 16 1980

GRAVER ENERGY SYSTEMS, INC

CD79 12080006

RIVER BEND PROGRAM, JOB ORDER NO. 61040N

CAUSE-AND-CORRECTIVE-ACTION ANALYSIS CONCERNING SUB-SURFACE DEFECTS FOUND IN RIVER BEND CORNER JUNCTION TEE WELDS

Summary Status Report

Prepared by: B. L. Baird *BLB*

Date: December 4, 1979

4809 TOD AVENUE, EAST CHICAGO, INDIANA 46312 • (219) 392-8300
An [illegible] Company

FOREWORD

This is a summary status report which recaps the results of prior work done on a cause-and-corrective-action analysis concerning sub-surface defects found in River Bend corner junction tee welds, and presents new information obtained from additional work performed on the investigation of this problem.

CONTENTS

1.0 INTRODUCTION

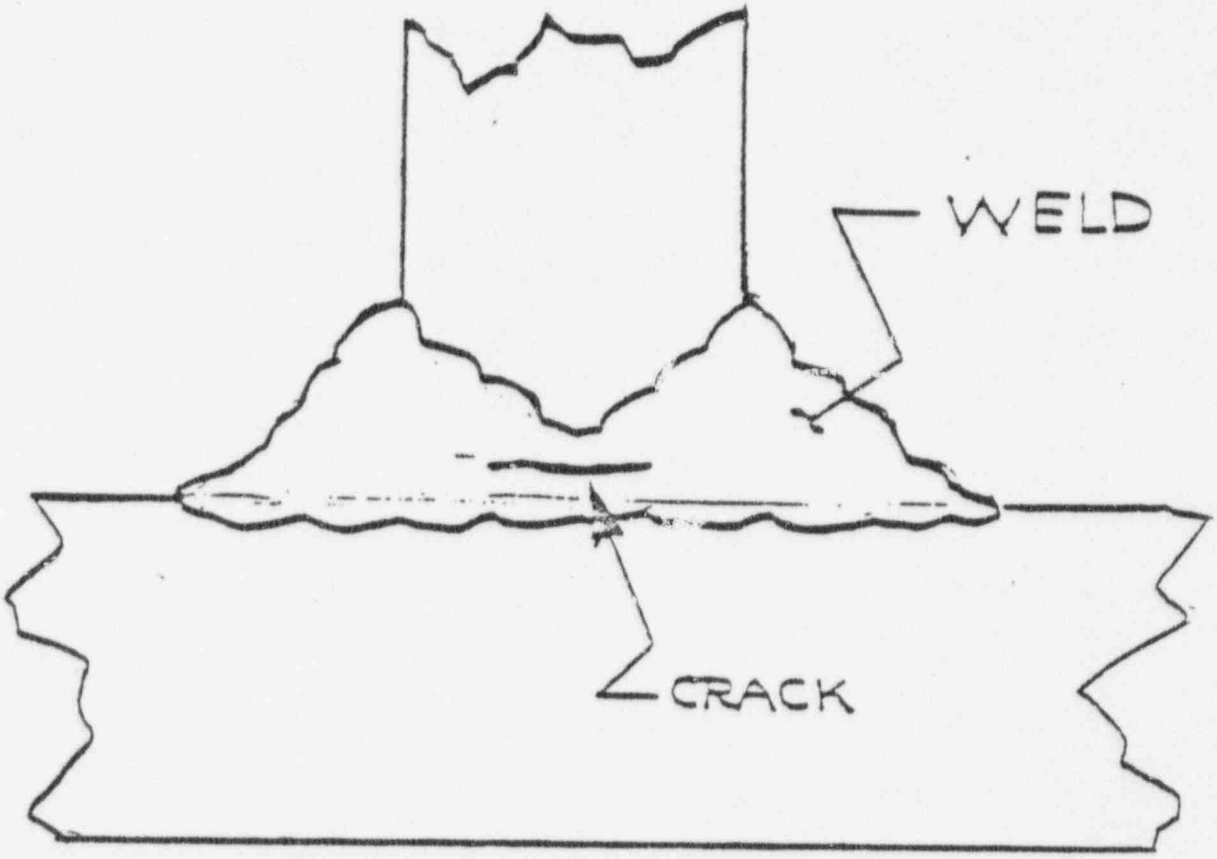
Graver Nonconformance Report (NCR) No. 77 (Reference (1)) covers a nonconformity in River Bend corner junction tee welds which were made, in conformance with Graver Welding Procedure 302N (Reference (2)), using a dual-head submerged arc automatic welding machine manufactured by Ogden Engineering Corporation and marketed under the model name DART 2108. These tee joints are a full-penetration, double-bevel groove weld. After fit up and tacking, one initial pass is made by hand welding. Subsequent passes are made using the DART 2108 submerged arc automatic welding machine. This dual-head machine deposits two passes, simultaneously, from both sides of the tee joint.

The nonconformity covered by NCR No. 77 is identified as "unacceptable linear discontinuities". Two prior reports, and one report supplement, covering investigative work done on this nonconformity have been written. (See References (3), (4) and (5).)

The unacceptable linear discontinuity which is the subject of the above earlier reports, as-well-as this particular report, is a crack produced in the root area, taking the form illustrated in the sketch contained in Figure 1.

The cause of the nonconformance identified in NCR No. 77 was unacceptable penetration characteristics of the first submerged arc pass due to; (a) major variations in welding current, and (b) variations in electrode position. The primary corrective action identified in NCR No. 77 was the modification of the submerged arc welding equipment used to make the corner junction tee welds in order to permit welding current and electrode position to be controlled.

After NCR No. 77 was written, Graver management made the decision that no additional corner junction tee welds would be made using Welding Procedure 302N (Reference (2)) until after major modifications to the DART 2108 automatic welding machine have been completed. In the interim since this decision was made, the welding of corner junction tee joints has been accomplished as a hand operation, in conformance with Graver Welding Procedure 305N (Reference (6)).



SKETCH OF CROSS-SECTION OF CORNER JUNCTION TEE WELD ILLUSTRATING THE CHARACTERISTIC CRACK WHICH IS THE SUBJECT OF THE CAUSE-AND-CORRECTIVE-ACTION ANALYSIS DISCUSSED IN THIS REPORT,

Figure 1

The cause and corrective action statements contained in NCR No. 77 were based on the investigative work summarized in a Graver report dated 7/2/79. (See Reference (3).)

On September 18, 1979, the contents of Reference (3) were reviewed at a joint Stone & Webster/Graver meeting. As a result of questions raised at this meeting, a decision was made to re-examine the cause-and-corrective-action analysis summarized in Reference (3). Reference (4) is a report, dated October 25, 1979, summarizing the results of this re-examination, and the conclusions drawn from it.

Reference (4) argued that NCR No. 77 (Reference (1)) and the July 2nd report (Reference (3)) were in error with regard to the identification of "major variations in welding current" as one of the two causes which produced the sub-surface cracks that are the critical defect covered by the nonconformance. (The second identified cause described in References (1) and (3) was "variations in electrode position". This was not challanged in the new set of conclusions presented in Reference (4).)

The October 25th report (Reference (4)) concluded the following:

(1) The welding current and voltage requirements identified in Welding Procedure 302N (Reference (2) were maintained when the corner junction tee welds were produced using the DART 2108 automatic welding machine; and lack of control of these parameters did not produce the sub-surface cracks.

(2) The two primary causes of the sub-surface cracks were:

(a) Use of low preheat, interpass, and post heat temperatures.

(b) Use of a sub arc electrode - flux combination which produces welds with more hardenability than is required.

(3) Based on the above identified causes, the recommended corrective actions are:

(a) Welds to be made in the future using Welding Procedure 302N:

1. Raise the preheat, interpass and post heat temperatures.

2. Change the sub arc electrode - flux combination to one which produces welds with minimum hardenability.

(b) Existing corner junction welds previously made using Welding Procedure 302N:

1. Re-examine the welds using an adequate UT testing technique.

2. Remove all rejectable defects and repair by hand welding using a welding procedure that includes adequate preheat, interpass, and post heat requirements.

On October 30, 1979, a draft of a plan covering additional work to be done to verify or disprove the conclusions contained in the October 25th report (Reference (4)) was prepared. (See Reference (7).) The plan called for the following:

(a) Weld, UT inspect and macro-section four corner junction tee joint mock-ups. The first would be welded, exactly as the corner junction tee joints were welded, using Welding Procedure 302N and the DART 2108 automatic welding machine. The second would be welded identically to the first, except that a minimum preheat/interpass/post heat temperature of 300°F would be employed. The third would be welded identically to the second, except that the welding wire would be changed from Linde 40 to Lincolnweld L-61 (a lower hardenability composition than Linde 40). The fourth would be welded identically to the third, except that the welding wire would be changed to Lincolnweld L-60 (a lower hardenability composition than Lincolnweld L-61).

(b) Make actual or simulated repair welds in the above four mock-ups using a procedure calling for 350°F preheat prior to arc gouging, followed by manual repair welding using a minimum preheat/interpass/post heat temperature of 300°F.

On October 31, 1979, the October 25th report (Reference (4)) and the plan covering additional work (Reference (7) were reviewed at a joint Stone & Webster/Graver meeting. At this joint meeting, S & W expressed some skepticism concerning the conclusions contained in the October 25th report concerning the probable influence of both preheat/interpass/post heat temperature, and welding rod hardenability, on the initiation of the sub-surface cracks covered by NCR No. 77. S & W also expressed the belief that the penetration characteristics (degree of penetration of the initial sub arc passes into the hand welded area at the root of the joint) of the initial submerged arc passes were of greater influence than either of the above.

In deference to the views expressed by S & W at the October 31st meeting, Graver agreed to revise the plan covering additional work as follows:

(a) The second mock-up would be changed to one welded identically to the first (per Welding Procedure 302N, using the DART 2108 automatic welding machine), with the exception that the number of hand passes would be increased from one to four, and the welding current to be used on the first four sub arc passes (made two-at-a-time from both sides of the joint) would be reduced by approximately 20%. The additional hand passes and the reduced current on the initial sub arc passes would be introduced in order to reduce the degree of penetration of the initial sub arc passes into the hand welded area at the root of the joint.

(b) The third mock-up would be deleted.

On November 5, 1979, Supplement No. 1 to the October 25th report was written. (See Reference (5).) This supplement was divided into two parts. Part 1 contains a revised plan for additional work, incorporating suggestions which evolved from the joint S & W/Graver meeting held on October 31st. Part 2 contains documentation supporting the conclusion contained in the

October 25th report (Reference (4)) that the welding current and voltage requirements identified in Welding Procedure 302N (Reference (2)) were maintained when the corner junction tee welds were produced using the DART 2108 automatic welding machine.

In the interim since November 5th, the work described in Part 1 of Reference (5) has been completed. This report presents the results of this new work.

2.0. NEW WORK COMPLETED SINCE THE LAST JOINT S&W/GRAVER MEETING

The plan covering the new work completed since the last joint S & W/Graver meeting (held on October 31, 1979) is defined in Part 1 of Reference (5). This plan covers a two-part program. Part A addresses the development of additional information pertinent to eliminating, or reducing the incidence of, the characteristic sub-surface crack illustrated in Figure 1; in cases involving new corner junction tee welds made with the sub arc process. Part B addresses the development of information which would be used as the basis for a repair procedure to be employed to repair existing corner junction tee joints welded, prior to May, 1979, using Procedure 302N and the DART 2108 submerged arc automatic welding machine.

2.1 Work Completed Under Part A

2.1.1 Mock-Ups

Four corner junction tee weld mock-ups were made using the DART 2108 dual-head submerged arc automatic welding machine. The Lincolnweld SA-750 motor generator sets supplying power to the machine were hooked up with the electrode leads coupled to the taps providing a relatively steep volt ampere output curve. This is the hook-up used when all River Bend corner junction tee welds were made with the DART 2108 machine. The mock-ups were welded as follows:

Mock-Up No. 1: Per Welding Procedure 302N

Mock-Up No. 2: Per Welding Procedure 302N with the following changes:

(a) Number of hand passes increased from one to four.

(b) Current on the initial two dual-head sub arc passes reduced by 100 amps. Weld wire diameter reduced from 1/8 inch to 3/32 inch for these passes.

Mock-Up No. 3: Per Welding Procedure 302N with the following changes:

Minimum preheat/interpass/post heat temperature raised to 300°F.

Mock-Up No. 4: Per Welding Procedure 302N with the following changes:

(a) Minimum preheat/interpass/post heat temperature raised to 300°F.

(b) Welding wire changed from Linde 40 to Lincolnweld L-60, a lower hardenability composition.

2.1.2 Instrumentation

(a) Current and Voltage:

The welding current and voltage output of each of the two automatic welding systems feeding power to the DART 2108 automatic welding machine were continuously recorded.

(b) Temperature:

In the case of Mock-Ups No. 1 and 2, the preheat and interpass temperatures were measured with temperature indicating crayons. In the case of Mock-Ups No. 3 and 4, the preheat/interpass/post heat temperatures were continuously measured by thermocouples and recorded on a chart. These temperatures were also checked with temperature indicating crayons.

2.1.3 Inspection

(a) Magnetic Particle:

After completing the root passes, and after completing the last sub arc passes, the mock-up welds were magnetic particle inspected.

(b) Ultrasonic Testing:

After completing the last sub arc passes, the mock-up welds were ultrasonic tested.

2.1.4 Destructive Testing

After inspection, the mock-ups were cut, and macro-sections were made at selected locations.

2.2 Results Obtained from the Work Completed Under Part A

2.2.1 Mock-Up No. 1

(a) Current and Voltage Charts:

The chart covering continuous recording of 2 hours, 18 minutes, 6 seconds of actual arc time was studied. There was no evidence on the chart of abnormal welding current or voltage.

(b) Magnetic Particle Inspection and Ultrasonic Testing:

No cracks were found.

(c) Macro-Sectioning:

Macro-sectioning indicated that the initial sub arc passes had not fully penetrated the hand welded root pass. The minimum width of hand welded root pass was in excess of 1/4 inch. (See sketch contained in Figure 2.)

2.2.2 Mock-Up No. 2

(a) Current and Voltage Charts:

The chart covering continuous recording of 2 hours, 11 minutes and 55 seconds of actual arc time revealed no evidence of abnormal welding current or voltage.

(b) Magnetic Particle Inspection and Ultrasonic Testing:

No cracks were found.

(c) Macro-Sectioning:

Macro-sectioning revealed that the initial sub arc passes had not fully penetrated the hand welded root passes. The minimum width of hand weld remaining in the root area was in excess of 1/2 inch. (See sketch contained in Figure 3.)

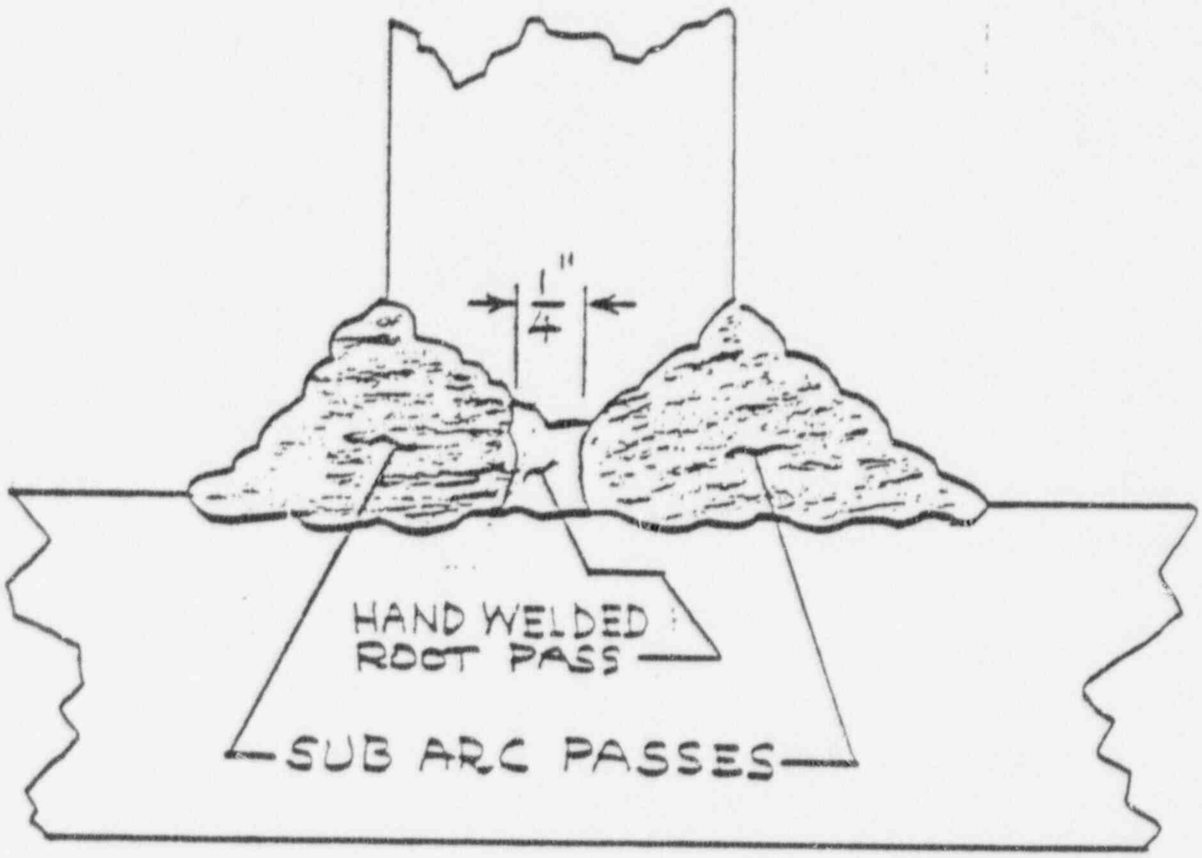
2.2.3 Mock-Up No. 3

(a) Current and Voltage Charts:

The chart covering continuous recording of 2 hours, 10 minutes and 10 seconds of actual arc time revealed no evidence of abnormal welding current or voltage.

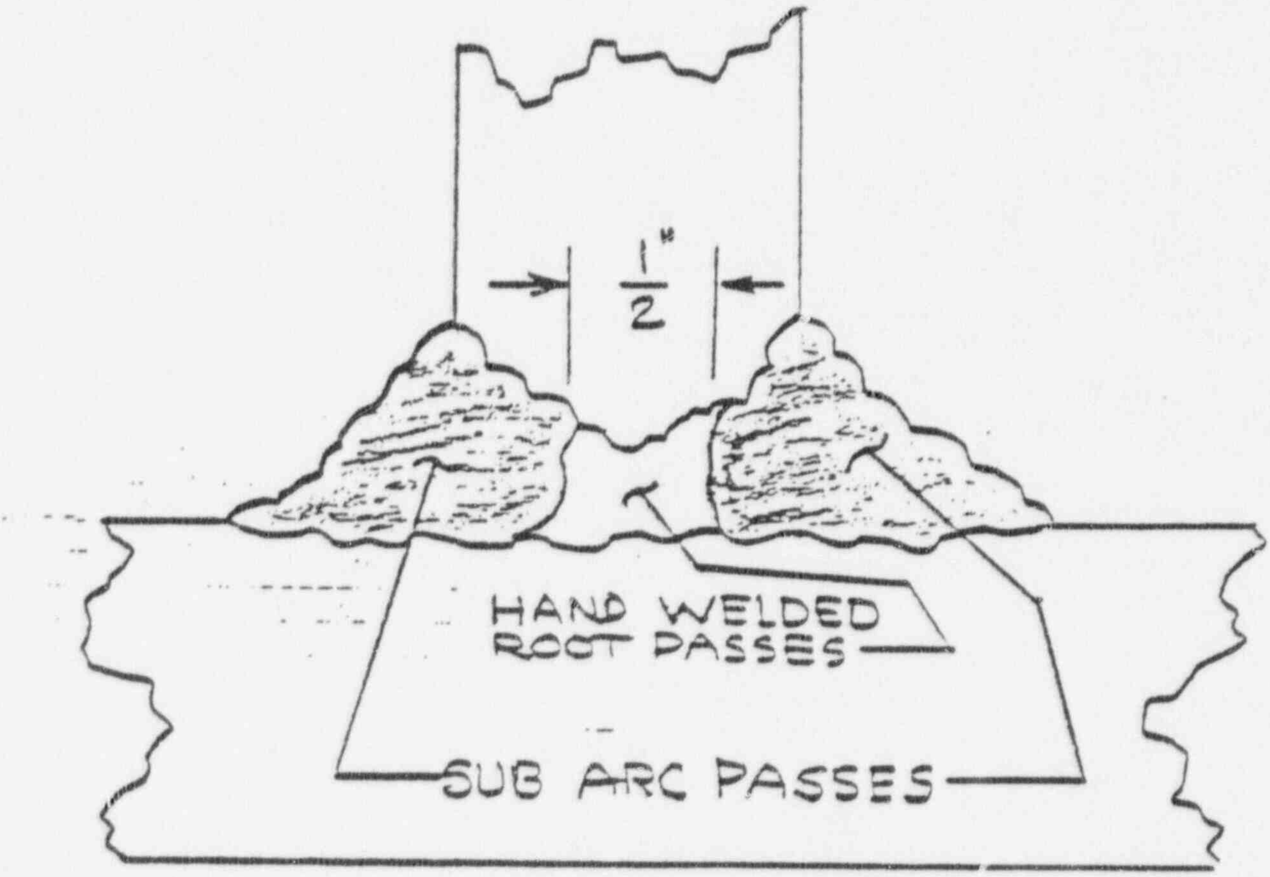
(b) Magnetic Particle Inspection and Ultrasonic Testing:

No cracks were found by magnetic particle inspection.



SKETCH OF MACRO-SECTION FROM MOCK-UP NO. 1

Figure 2



SKETCH OF MACRO-SECTION FROM MOCK-UP NO. 2

Figure 3

Ultrasonic inspection indicated the presence of nine cracks in the weld root area, ranging in length from 1 to 11-1/4 inches.

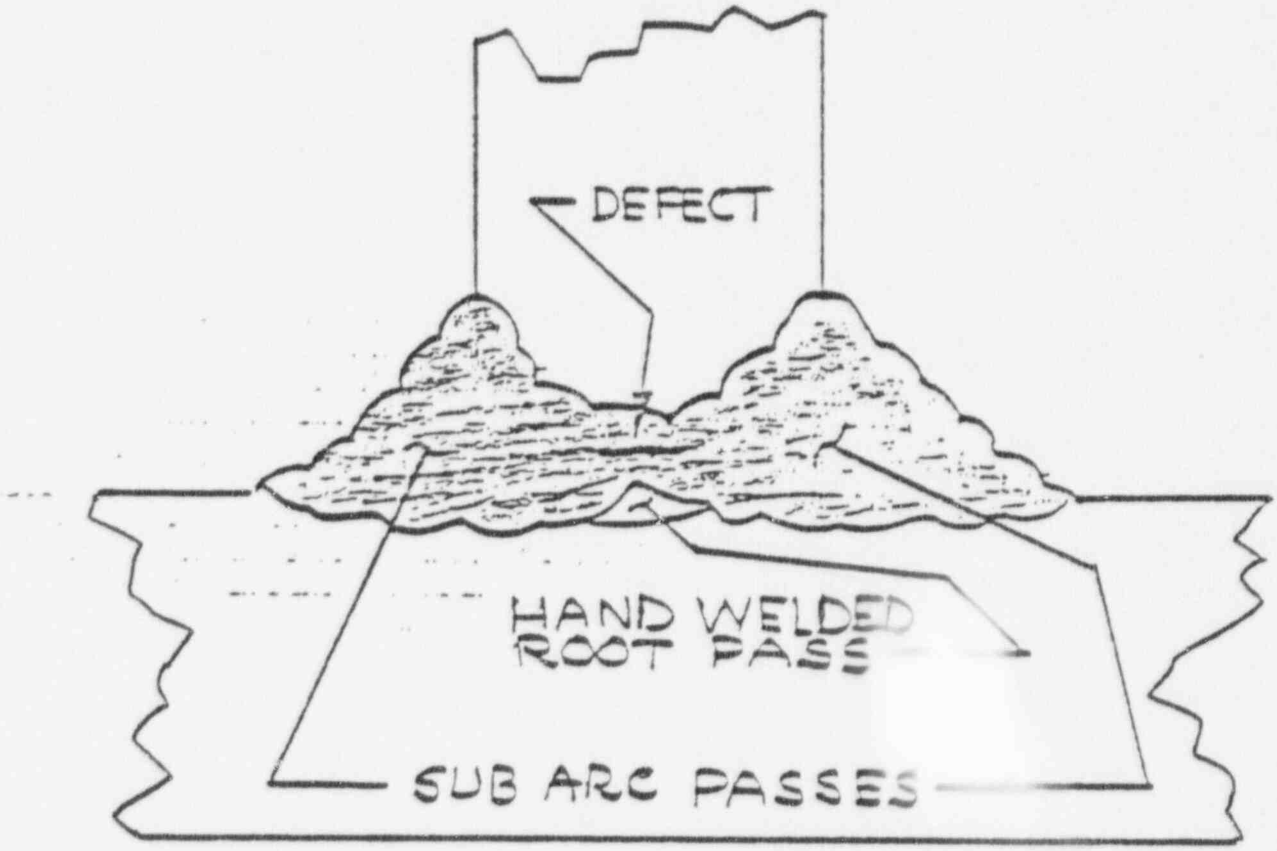
(c) Macro-Sectioning:

Macro-sectioning revealed that the initial sub arc passes had fully penetrated the hand welded root pass. The sketch contained in Figure 4 illustrates the degree of penetration present.

2.2.4 Mock-Up No. 4

The sub arc welding on Mock-Up No. 4 was stopped after completion of the first dual-head pass. When the sub arc weld was initiated, one head started erratically and then settled down after about four inches of welding. Therefore, this area was arc gouged in preparation for hand weld touch-up prior to starting the second dual-head pass. The arc gouging revealed the presence of a crack in the root area, approximately 1/4 inch below the surface, and at least 4 inches in length. The sub arc weld was magnetic particle inspected in the arc gouged area, and for a distance of about 6 inches down stream from the arc gouge. This revealed that the crack did not penetrate through to the surface of the sub arc weld. After magnetic particle inspecting this area of the weld, a decision was made to discontinue sub arc welding and explore the joint by macro-sectioning.

Three macro-sections were made; in the arc gouged area, 6-3/4 inches down stream from the arc gouged area, and 13-1/8 inches down stream from the arc gouged area. At 6-3/4 inches down stream from the arc gouged area there was no evidence of the crack. At 13-1/8 inches down stream, the crack reappeared.



SKETCH OF MACRO-SECTION FROM MOCK-UP NO. 3

Figure 4

2.2.4.1 Current and Voltage Charts

The chart covering continuous recording of 11 minutes, 40 seconds of actual arc time revealed no evidence of abnormal welding current or voltage.

2.2.4.2 Macro-Sectioning

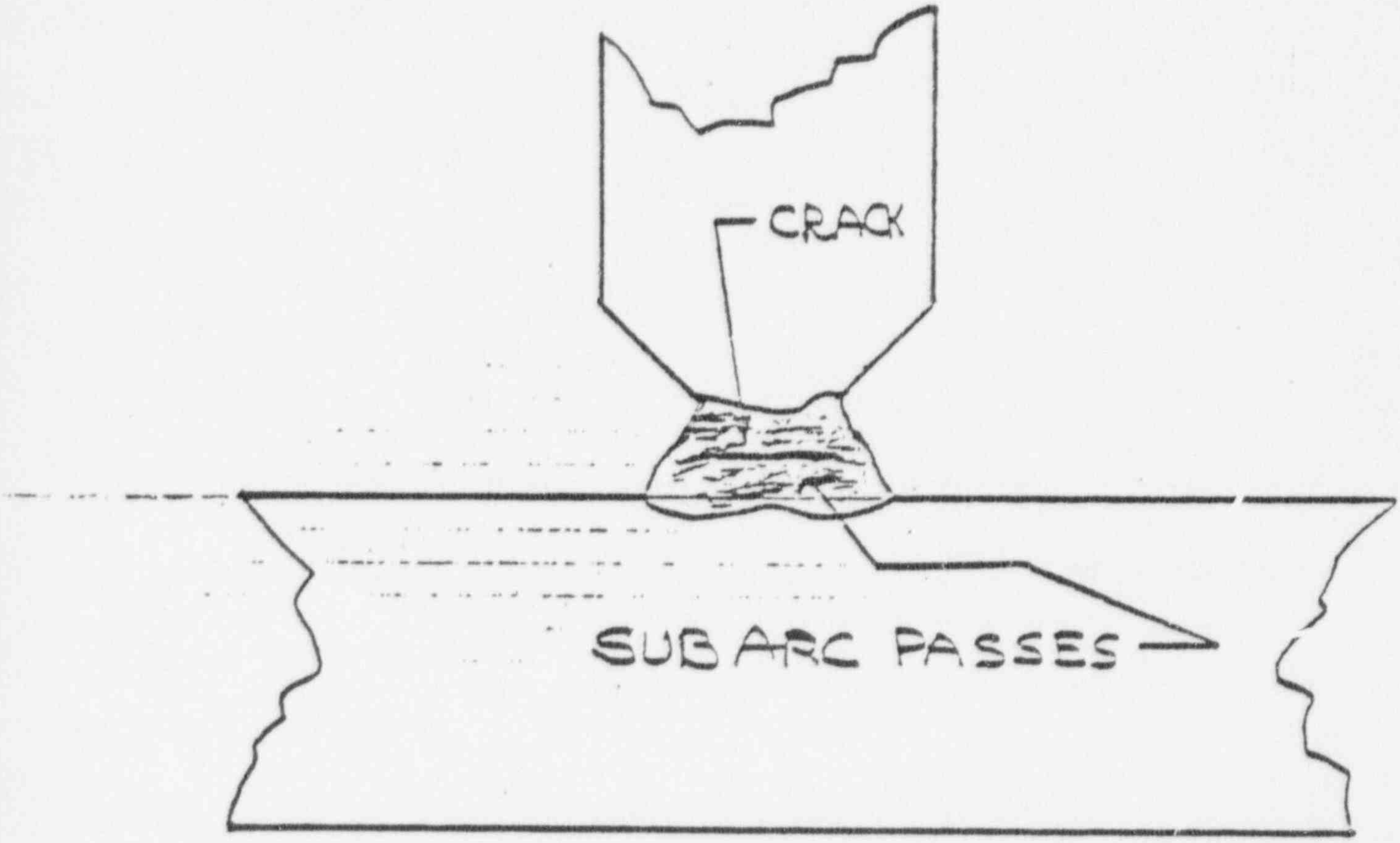
Macro-sectioning revealed that the initial sub arc passes had fully penetrated the hand welded root pass. The macro-sections showed that 100% of the root pass weld had been melted when the initial dual-head sub arc pass was made. The sketch contained in Figure 5 illustrates the degree of penetration which occurred.

2.3 Interpretation of the Results Obtained from the Work Completed Under Part A

The work completed in Part A consisted of the making and evaluation of four one-of-a-kind test articles. One is a very small sample size, and there are risks associated with any attempt to draw definite conclusions from a sample of only one. These risks not withstanding, the results obtained from the work completed in Part A appear to indicate the following:

(1) Raising the preheat/interpass/post heat temperature to 300°F will not eliminate the sub-surface cracks, nor reduce their incidence. Including the work reported in References (2) and (3), as-well-as the work covered by this report, it has been demonstrated that the sub-surface cracks have been produced at preheat temperatures of (a) ambient temperature, (b) 200°F and (c) 300°F.

(2) Changing the composition of the welding wire to the lowest hardenability composition acceptable under ASME Specification SFA 5.23 will not eliminate the sub-surface cracks nor reduce their incidence.



SKETCH OF MACRO-SECTION FROM MOCK-UP NO. 4

Figure 5

(3) Preventing deep penetration of the hand welded root pass will reduce the incidence of the sub-surface cracks, and may even completely eliminate these defects. This can be accomplished by increasing the number of hand passes made before commencing sub arc welding, and by reducing the welding current used on the initial sub arc passes.

(4) NCR No. 77 (Reference (1)) is incorrect. Major variations in welding current played no role in the initiation of the sub-surface cracks which are covered by the nonconformance described in NCR No. 77. There were no abnormal current variations produced when the River Bend corner junction tee joints were welded, in conformance with Welding Procedure 302N, using the DART 2108 automatic welding machine.

(5) Repair of sub-surface cracks in existing corner junction tee welds need not be done by a special repair procedure incorporating requirements for preheating prior to arc gouging, plus requirements for preheat/interpass/post heat temperatures of 300°F or higher. Repair may be accomplished using existing Graver Welding Procedures 305N and RP-1 (Reference (6) and (8), respectively).

2.4 <u>Discussion of the Results Obtained from the Work Completed Under Part A</u>

The sub-surface cracks, which are covered by NCR No. 77 (Reference (1)) and illustrated in Figure 1, are probably the result of a solidification phenomenon, related to the convergence of two solidification fronts.

Graver Welding Procedure 302N calls for an electrode spacing (relative distance between the tips of the two electrodes, measured in a direction parallel to the direction of travel) of 1/2 inch to 2 inches. It is the Graver shop practice to set this distance before starting a series of

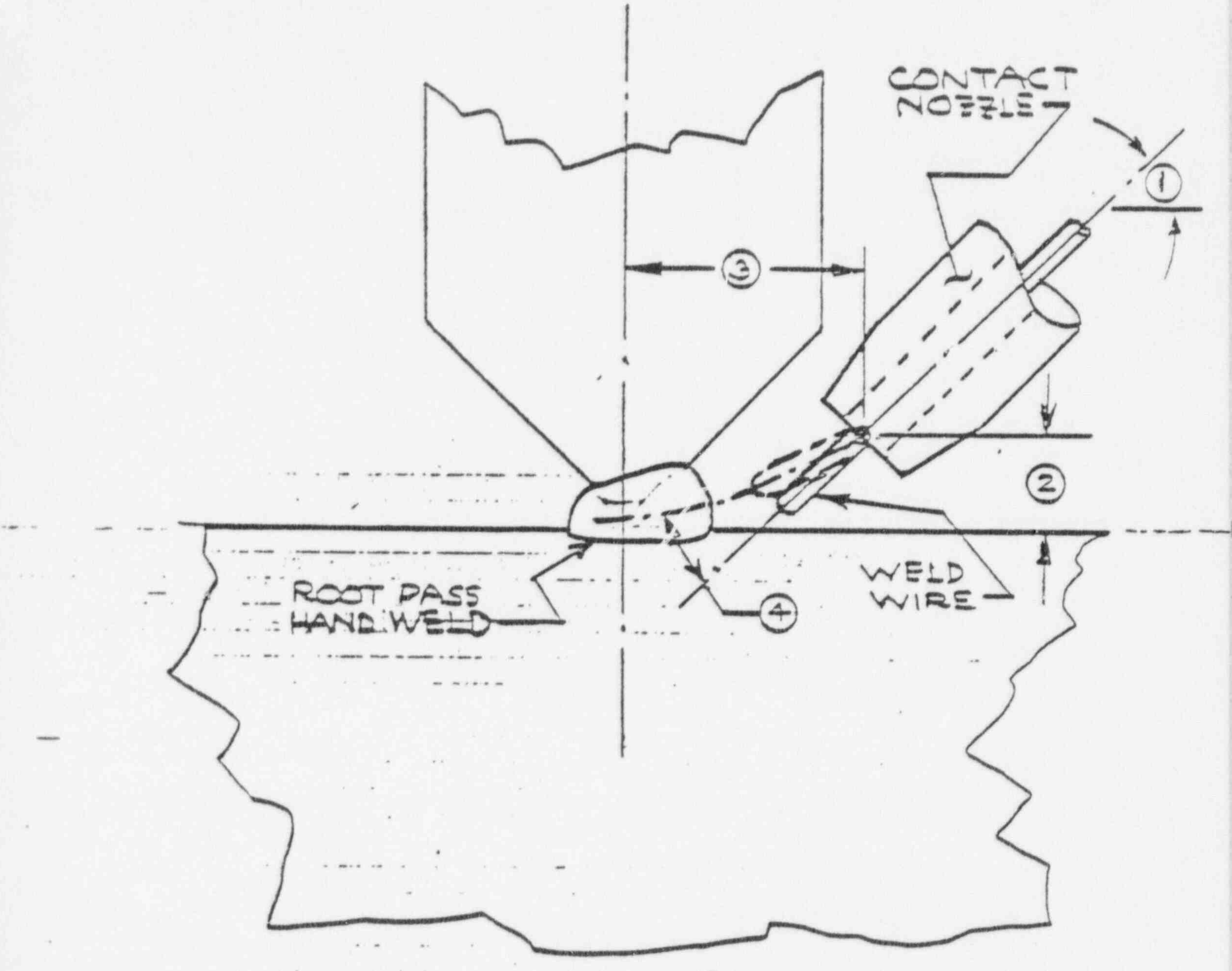
welds, and leave it fixed throughout the series. In the case of the welds made on Mock-Ups No. 1 - 4, the spacing was set at approximately 2 inches when the welds were made on Mock-Up No. 1; and it remained at this distance when the welds were made on Mock-Ups 2 - 4.

The position of the electrode with respect to its orientation relative to the center-line of the weld joint is not specified in Procedure 302N. It is Graver shop practice to set this position, before the initiation of the first dual-head sub arc pass, based on a visual check made by the operator, and his judgment regarding proper positioning. As subsequent passes are made, the position is checked prior to initiating the weld, and adjustments are made.

Differences in electrode position probably account for the fact that on Mock-Up No. 1 the initial sub arc passes did not fully penetrate the hand welded root pass, while on Mock-Ups 3 and 4, the initial sub arc passes did fully penetrate the hand welded root pass.

It may be possible to prevent the initiation of the sub-surface cracks by proper adjustment of electrode position, as described in NCR No. 77. However, electrode position is not an essential variable identified in Section IX of the ASME Boiler and Pressure Vessel Code. Furthermore, electrode position is very difficult to identify quantitatively, and almost impossible to inspect accurately.

In order to attempt to control electrode position, and thus prevent the initiation of the sub-surface cracks, it would be necessary to define values for dimensions ① through ④ , shown in Figure 6, and inspect to verify adherence to these values prior to initiation of the initial sub arc pass. This would be very difficult to accomplish. Angle ④ , in particular, would be virtually impossible to control, since it is influenced by both the wear on the bore of the contact nozzle and the amount of welding wire left on the spool.



CRITICAL ELECTRODE POSITION
DIMENSIONS

Figure 6

For the above reasons, the approach reflected in Mock-Up No. 2 is probably the only practical method that can be used to prevent, or minimize, the initiation of sub-surface cracks when corner junction tee joints are welded using Procedure 302N and the DART 2108 dual-head submerged arc automatic welding machine. This would involve changing Welding Procedure 302N to require that at least four hand passes be made prior to initiation of sub arc welding, plus reducing the current used on the initial dual-head sub arc pass by at least 100 amps.

2.5 Work Completed Under Part B

2.5.1 Ultrasonic Testing of River Bend Unit 2 Corner Junction Tee Welds

Four Unit 2 corner junction tee welds were ultrasonic tested, using dual 60° transducers, to inspect for the presence of sub-surface cracks in the root area of the joint. The results of this testing are summarized in Table 1.0.

2.5.2 Repair Welding

The three crack indications in the corner junction identified as 3-E30 (see Table 1.0) were removed by arc gouging. The local area in the vicinity of the indication was preheated to a minimum temperature of 300°F prior to arc gouging.

The arc gouging was interrupted when the indications became visible. Two of the indications appeared to be slag, although this was not verified. The third indication had more the appearance of a crack than of slag.

Two of the three defect cavities were repaired by hand welding. One was repaired using a minimum preheat/interpass/post heat temperature of 300°F. The other was repaired using Graver Welding Procedures 305N (Reference (6)) and RP-1 (Reference (8)).

TABLE 1.0 RESULTS OF ULTRASONIC TESTING OF RIVER BEND UNIT 2 CORNER JUNCTION TEE WELDS USING DUAL 60° TRANSDUCERS

Identification of Unit 2 Corner Junct.	Length of Corner Junct. Weld That was UT Inspected	Crack Indications in the Root Area of the Joint					
		Number	Length (Inches)	Total No. of Indications	Total Lgth. of all Ind. in Cor. Junct. (Inches)	Total Lgth. of all Ind. Divided by Lgth. of Cor. Junct. Inspected	% Total Cor. Junct. Lgth. Occupied by Indications
3-E30	123	1	1	3	3-1/2	.028	3
		2	1-1/2				
5-E30	178-1/2	2	1	5	6-3/4	.038	4
		1	1-1/2				
		1	1-3/4				
		1	2-1/2				
6-30	177	1	3	2	8-1/4	.047	5
		1	5-1/4				
22-E30-1	177	5	1	10	21.5	.121	12
		1	1-1/2				
		1	3				
		1	4				
		1	5-1/2				
		1	6-1/2				

Total length of weld that was UT inspected = 655.5 inches
Total length of all crack indications found in the root area of the joint = 40 inches
Per cent of total weld length (all four corner junctions) occupied by crack indications in the root area of the joint = 6.1%

After completing the repair welds, they were magnetic particle inspected and ultrasonic tested. No crack indications were found in either repair weld.

3.0 REFERENCES

(1) Graver Nonconformance Report (NCR) No. 77, dated 5/22/79 (signed off on 6/27/79)

(2) Graver Welding Procedure Specification No. 302N

(3) Graver report dated 7/2/79, Title: Report on Examination of Corner Junction T-Welds & Stiffener Assemblies CS5, River Bend Unit 1 PD No. RBD-294

(4) Graver report dated 10/25/79, Title: Cause-and-Corrective-Action Analysis Concerning Sub-Surface Defects Found In River Bend Corner Junction Tee Welds

(5) Supplement No. 1 to Reference (4), dated 11/5/79

(6) Graver Welding Procedure Specification No. 305N, Title: Procedure Specification for Shielded Metal Arc Welding

(7) Draft # 1, dated 10/30/79, Title: Plan Covering Additional Work Concerning Sub-Surface Defects Found in River Bend Corner Junction Tee Welds

(8) Graver Welding Procedure Specification No. RP-1, Title: Procedure for Weld Repair of Base Metal

ENCLOSURE II

RBS-4612

METALLURGICAL INVESTIGATION

River Bend Units 1 and 2
Containment Corner Junction Weldment

GULF STATES UTILITIES COMPANY
Beaumont, Texas

January 1980
J.O. 12210

Prepared by:

R. P. Indap
R. P. Indap
Materials Engineering

Approved by:

A. W. Latti
A. W. Latti
Assistant Division Manager
Materials Engineering

STONE & WEBSTER
ENGINEERING CORPORATION
Cherry Hill Operations Center
Cherry Hill, New Jersey

METALLURGICAL INVESTIGATION
River Bend Units 1 and 2
Containment Corner Junction Weldment

SUMMARY

This report describes the metallurgical investigation undertaken to determine the cause of cracking in River Bend Units 1 and 2 containment shell to mat embedment plate tee weld (corner junction). This investigation was also undertaken to determine if a proper metallurgical structure exists for the weld and its heat-affected zone if it were decided to simply remove the cracks and use the remaining weld. It was determined that the crack was actually a centerline linear shrinkage-voids, interconnected by fine cracks, which occured during solidification of the undesirable weld nugget or bead shape deposited at the root. If the defect is removed, the remaining weld material is metallurgically acceptable to the ASME Section III, Class MC Code requirements.

INTRODUCTION

The corner junction assembly is designed and fabricated to ASME Section III, Class MC, 1974 Edition. It consists of a 1 1/2-inch thick embedment plate made from SA-516 Grade 70, electroslag remelted, normalized carbon steel welded to 1 1/2-inch thick containment shell plate, made from SA-516 Grade 70 normalized carbon steel, roll bonded with stainless steel Type 304L cladding. The shell plate was solution annealed at 2,025°F and then normalized at 1,650°F. Figure 1 shows the weld joint detail design. A single root pass was made with shielded metal arc welding (SMAW) using a 5/32-inch diameter, E7018 electrode. The remaining weld was completed with submerged arc welding (SAW) process by employing twin electrodes. The equipment used consisted of a DART 2108 automatic welder made by Ogden Engineering Corporation with Lincoln power source. Attachment 1 gives the welding procedure used by Graver Energy Systems to make this weld.

The completed weld was examined ultrasonically in accordance with ASME Section III, NE-5000 requirements. The original examination was performed by a 45-degree angle beam, and the weld was found acceptable. Subsequently, it was identified that the technique used was inadequate and that the weld must be reexamined by a 70-degree angle beam as a minimum. This technique showed that the weld root contains planar indications. Exploratory grinding and air-arcing confirmed that these indications were the result of a crack-like linear defect in the weld metal root area.

Sections representing the defective weld root area and sound weld were cut from a Unit 2 assembly (No. 3E30-1) for this investigation. The samples were sectioned as shown in Figure 2. Section 2 contained root area indications, and Section 1 had a sound weld based on ultrasonic examination. The following tests and examinations were performed for this investigation:

1. Macroscopic and metallographic examination of weld metal, base metal, and heat-affected zone (HAZ).

2. Scanning electron microscopy of defect surface.

3. Microhardness survey of defective weld.

4. Charpy impact of weld metal and heat-affected zone.

5. Chemical analysis of the following:

    a. Weld metal near defect.

    b. Sound weld metal in weld beads away from defect.

    c. Base metal containment shell plate.

    d. Base metal embedment plate.

Results of Macroscopic and Metallographic Examination

Figure 3 shows a polished and etched cross-section specimen containing the defect in the root area. This specimen shows all weld beads. The SAW pass in the root area was deposited from both sides of the shell plate and forms a single large bead, approximately 1 inch deep by 1/2 inch wide with a centerline defect. This bead remelts and consumes part or all of SMAW bead. Figures 4A and 4B show the microstructure near the defect. The microstructure consists of boundary ferrite (light area), acicular ferrite, and carbides (dark etched) (References 1 and 2). Figure 5 shows the weld metal metallurgical structure away from the root, which is the same as the weld metal structure near the defect. Figure 6 shows the heat-affected zone in the shell plate. The structure consists of prior austenite grain boundaries surrounding bainite colonies. Figures 7A and 7B show the base metal structures which are ferrite (light areas) and pearlite (dark areas).

These metallurgical structures show expected conditions and are considered normal.

Scanning Electron Microscopy

The specimen crack-like defect was opened to expose its surface. Figure 8 shows the defective surface. Figures 9 and 10 show this surface as viewed by a scanning electron microscope. In Figure 9, the surface topography is shown as globular and not fibrous, which confirms a welding-related shrinkage solidification defect.

Microhardness Testing

Figure 11 shows the locations where microhardness readings were taken. Table 1 lists the results of the microhardness survey; the hardness values are within expected values in all areas.

Charpy Impact Testing

Figure 12 shows locations at which Charpy-vee notch (Cv) impact specimens were taken. The Cv testing performed in the embedment plate was a through-thickness direction test. The specimens taken from the heat-affected zone (HAZ) were oriented in such a manner as to include as much of the HAZ as possible, as required by NE-4334.2. The results of Charpy tests are given in Table 2.

ASME Section III, NE-2300, acceptance criteria require a 20 ft/lb energy value at 30°F less than the lowest service temperature. Initial testing temperature was 0°F, which is 70°F below the lowest service temperature. Specimens which had unacceptable Cv values at 0°F were retested at 40°F to represent actual code requirements, and all Cv values were found to be acceptable.

Chemical Analysis

The chemical analysis results shown in Table 3 are typical for the base materials, wire and flux combination used.

DISCUSSION

Figure 3 shows that the crack-like defect is located approximately at the center of the first SAW passes. Figure 4A shows that the defect consists of a series shrinkage-voids connected by the fine cracks. The appearance of the defect can be understood by considering the progress of solidification of the first SAW passes.

Solidification of molten weld metal due to the quenching effect of the base metal starts along the sides of the weld metal and progresses inward by growing columnar grains. The last liquid metal to solidify lies in a plane through the centerline of the weld. If the weld depth is greater than the width of the face, the weld bead surface usually solidifies prior to center solidification. This prevents flow of liquid weld metal to the center to compensate for liquid to solid shrinkage and causes centerline shrinkage-voids. Further, the shrinkage stresses rupture or crack any solid weld metal connecting these shrinkage-voids, as shown in Figure 4A.

The scanning electron microscopy examination of the defect surface showed the globular topography interdendritic structure, which indicates that the defect was shrinkage-related, and occured during solidification of the weld nugget or bead.

It should be noted that the observed root weld centerline defect is only in the first weld pass. Subsequent passes have proper weld nugget or bead shape and do not have centerline indications or defects.

To preclude this type of defect in SAW's requires that neither the <u>depth</u> nor the <u>maximum width</u> in the cross section of the weld metal deposited in each weld pass <u>shall exceed the width</u> at the surface of the weld (Reference 3).

The metallurgical structures observed in the weld metal HAZ's and base materials are all considered normal and acceptable.

The microhardness survey shows that the hardness values are normal for the weld metal, plate HAZ's, shell plate, and embedment plate.

The Cv testing results indicate that weld metal has more than adequate toughness in all areas. The Cv specimens from the HAZ show lower toughness than base metal; however, this is considered normal for the welding process employed and materials used.

CONCLUSIONS

The crack-like defect in the containment corner junction weld consists of centerline linear shrinkage-voids interconnected by fine cracks. This defect was caused by undesirable bead weld nugget or bead shape deposited, due to either insufficient SMAW passes, too high input in SAW initial passes, or insufficient staggering between opposing SAW arcs. Evidence of unacceptable metallurgical structure was not observed for properly solidified weld areas.

Removing the root defect and rewelding with proper welding parameters can be employed to restore the containment corner welds to ASME Section III, Class MC code requirements.

RECOMMENDATIONS

In SAW, bead shape control is an important factor for making sound welds. Special attention should be given to this during development of the welding procedure. Neither the depth nor the maximum width in the cross section of weld metal deposited in each weld pass should exceed the width at the surface of the weld pass. Weld bead dimension should be checked and measured by sectioning and etching a sample weld.

When the width of deposited weld metal exceeds 1 inch, as in the multiple electrode SAW that was employed, the arcs should be separated to properly control solidification and crack-free welds. Another improvement would be to separate the electrodes completely by more (possibly three minimum) SMAW root passes, and then back gouge before the twin electrode SAW process is employed.

REFERENCES

1. Glover, A. G., et al. <u>Welding Journal</u>, September 1977, p. 267.

2. Choi, C. L., and Hill, D. C., <u>Welding Journal</u>, August 1978, p. 232.

3. AWS D1.1, <u>Structural Welding Code</u>, 1975, American Welding Society.

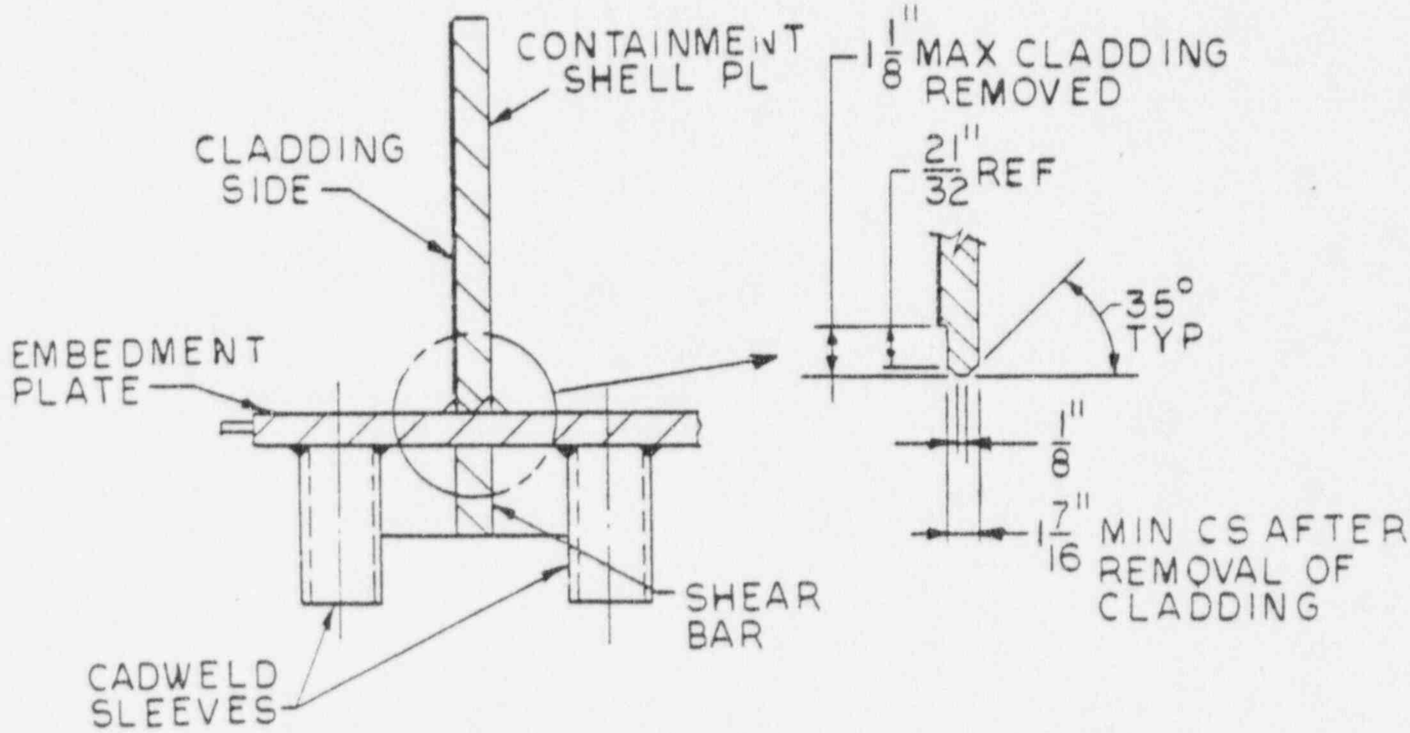
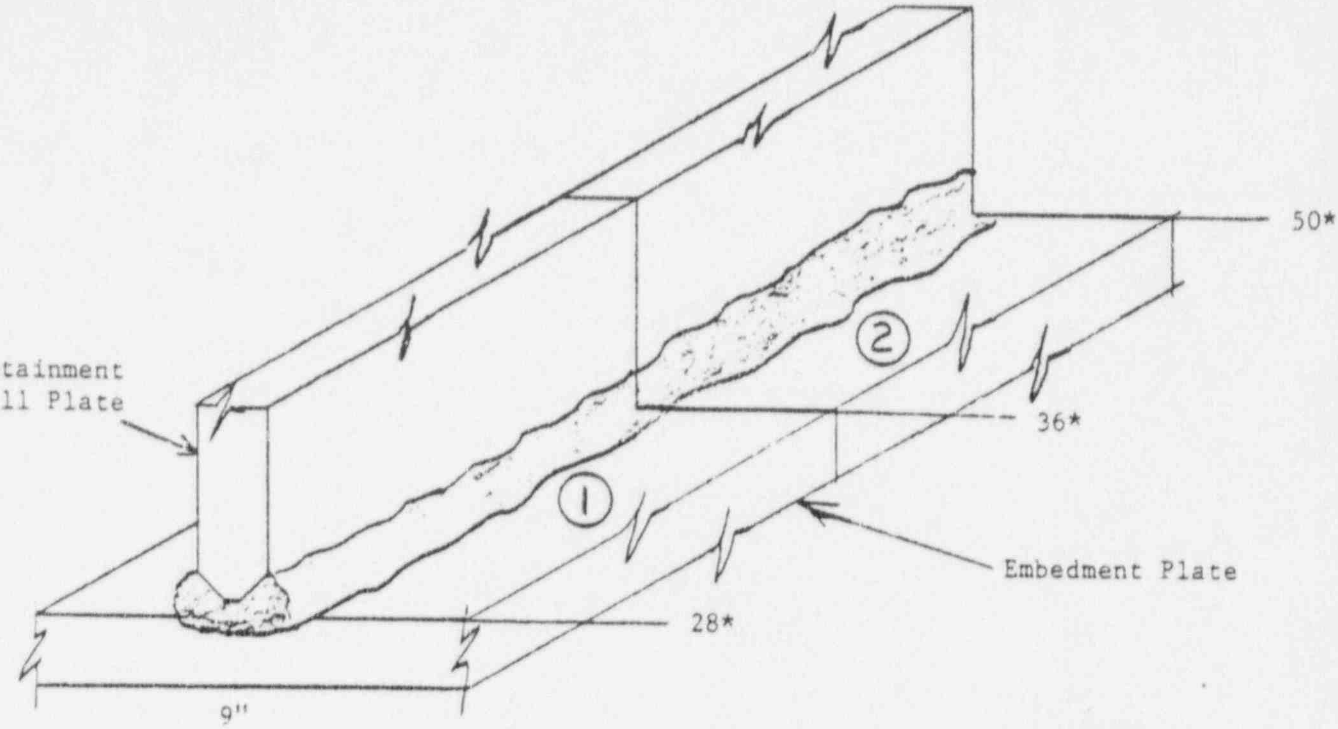


FIGURE 1 CORNER JUNCTION
WELD JOINT DETAIL

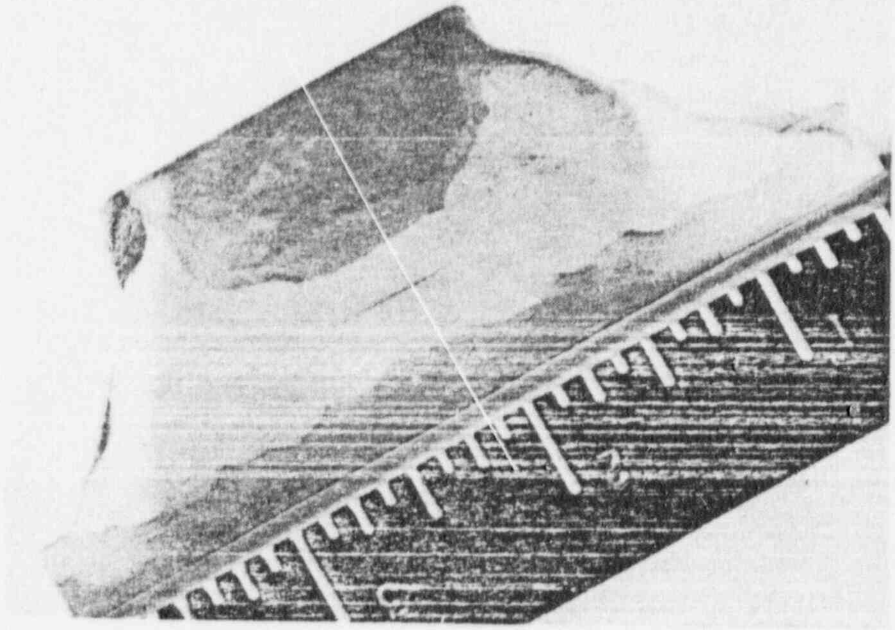


*Distance from reference end of the assembly in inches

SECTION 1 - SECTION CONTAINING SOUND WELD USED FOR CHARPY IMPACT TEST SPECIMENS.

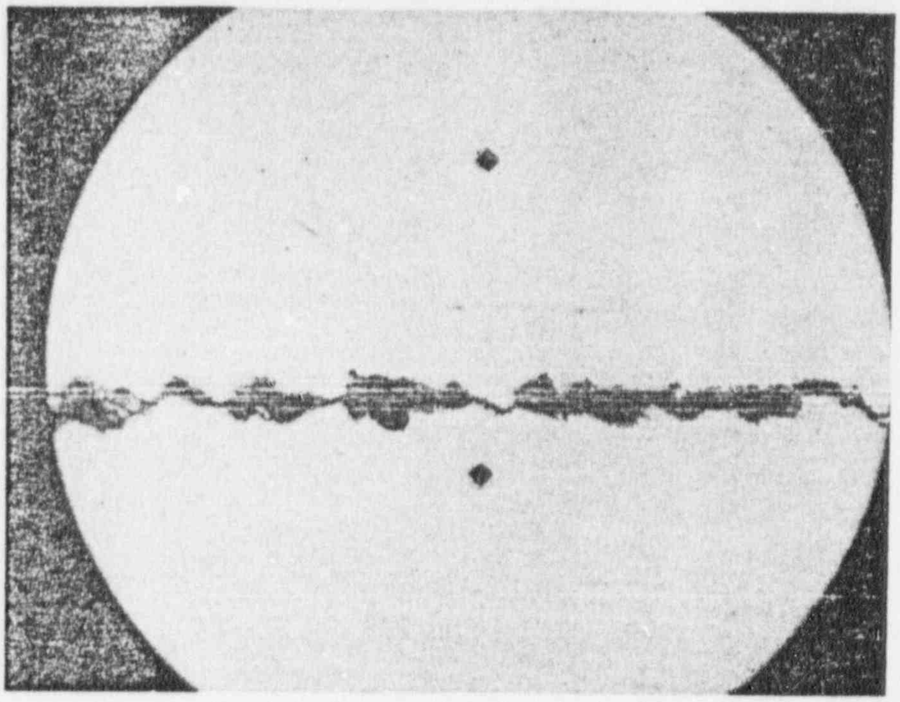
SECTION 2 - SECTION CONTAINING CRACKED WELD USED FOR METALLOGRAPHY, HARDNESS AND CHEMICAL ANALYSIS SPECIMENS.

FIGURE 2 CONTAINMENT CORNER JUNCTION T-WELD SECTION USED FOR METALLURGICAL INVESTIGATION



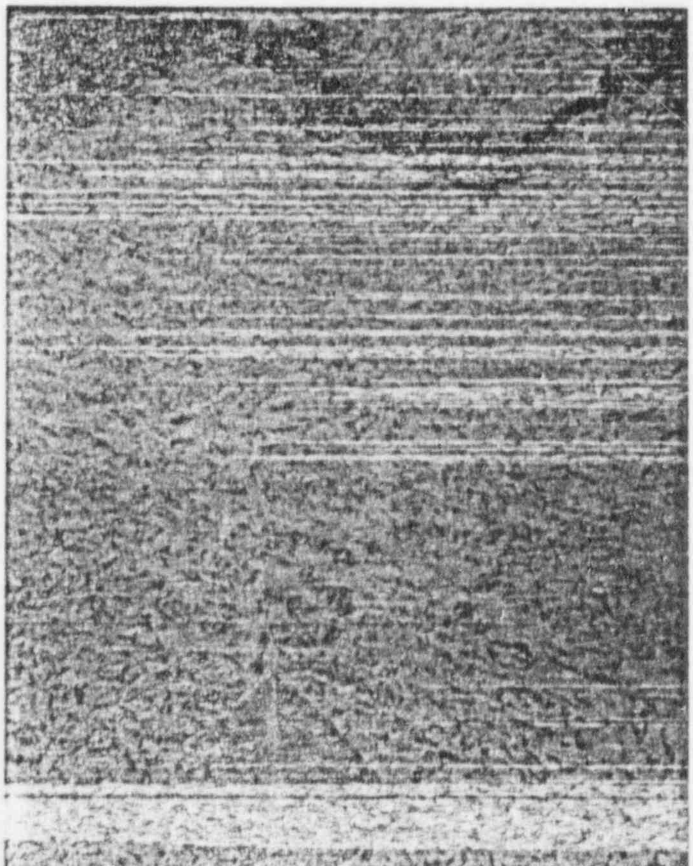
ETCHANT - 3%NITAL

FIGURE 3 CROSS SECTION SHOWING DEFECT IN THE ROOT AREA



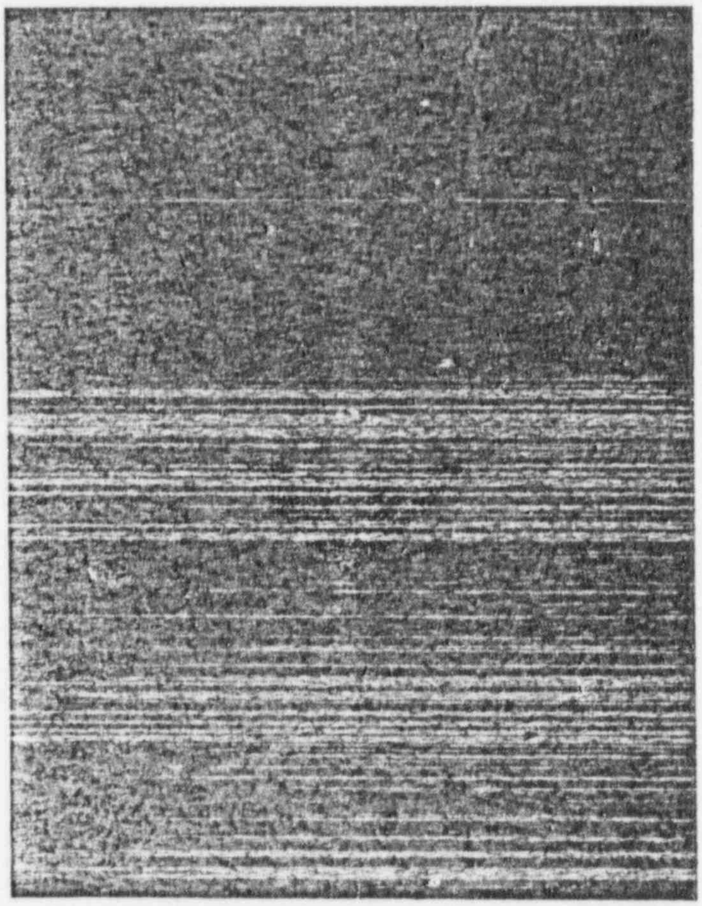
MAG. 50x
ETCHANT-2% NITAL

FIGURE 4A CENTER PORTION OF THE DEFECT ALONG WITH TWO DIAMOND PYRAMID HARDNESS INDENTATIONS



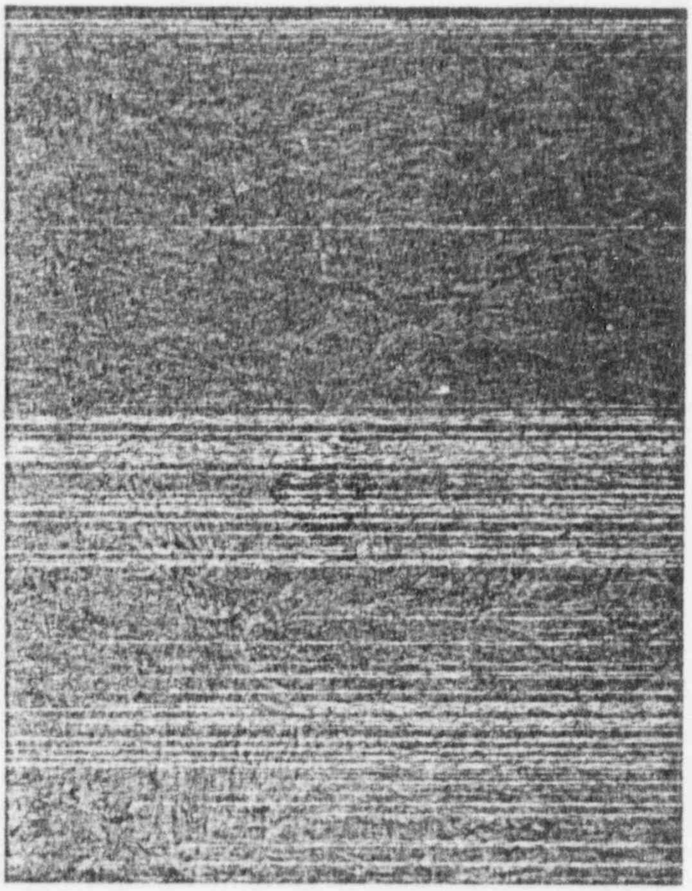
MAG. 500x
ETCHANT-2% NITAL

FIGURE 4B WELD METAL MICROSTRUCTURE NEAR DEFECT. (THE MICROSTRUCTURE CONSISTS OF BOUNDARY FERRITE, ACICULAR FERRITE, AND CARBIDE.)



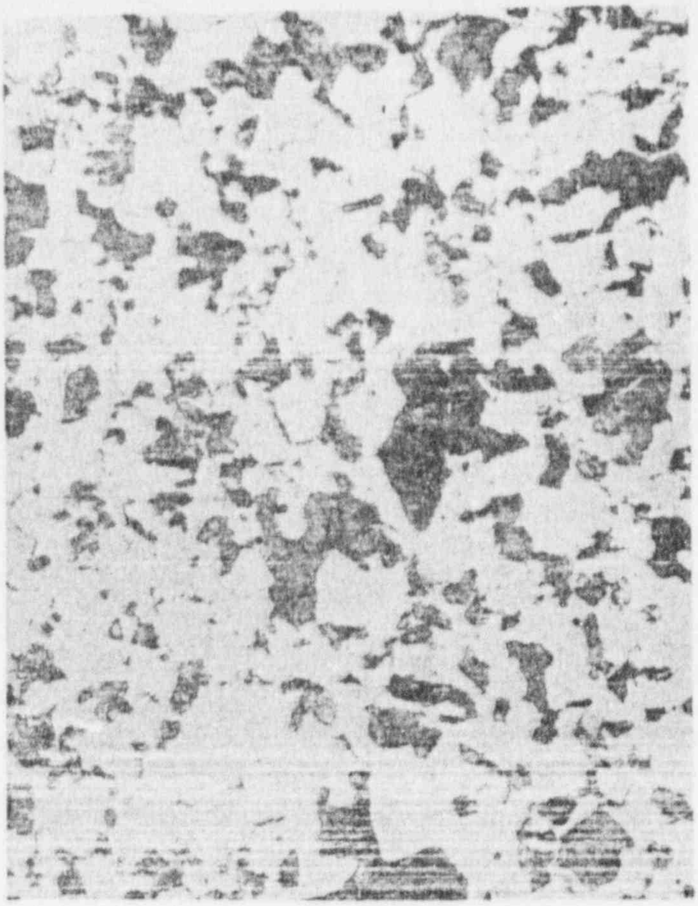
MAG. 500x
ETCHANT-2% NITAL

FIGURE 5 MICROSTRUCTURE IN THE SOUND WELD BEADS AWAY FROM DEFECT. (THE MICROSTRUCTURE CONSISTS OF BOUNDARY FERRITE, ACICULAR FERRITE, AND CARBIDE.)



MAG. 250x
ETCHANT -2% NITAL

FIGURE 6 MICROSTRUCTURE OF HAZ ABOVE THE CENTER BEAD IN CONTAINMENT SHELL PLATE. (THE MICROSTRUCTURE SHOWS PRIOR AUSTENITIC GRAIN BOUNDARIES SURROUNDING BAINITE COLONIES.)

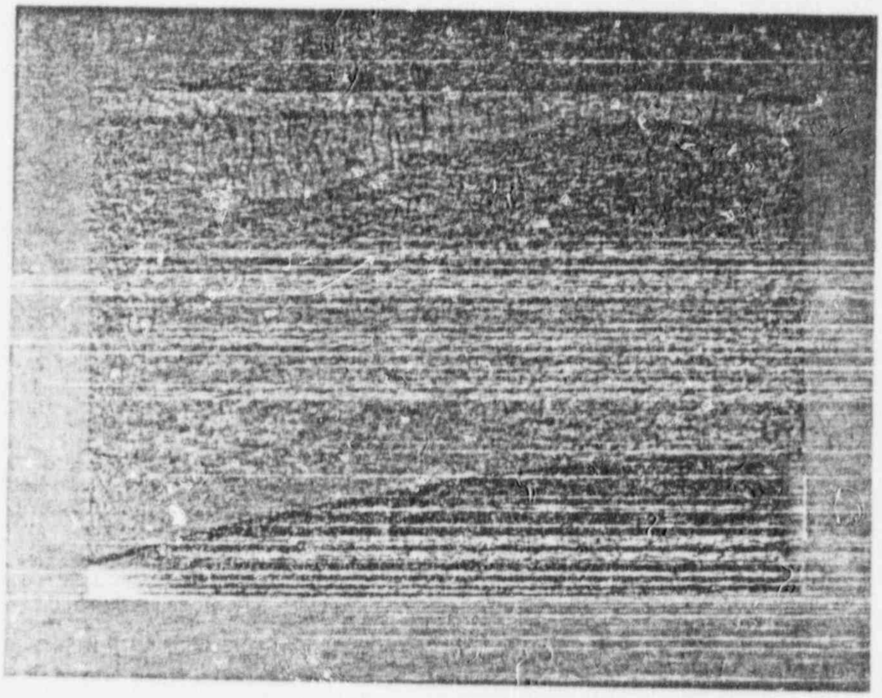


MAG. 500x
ETCHANT-2% NITAL

FIGURE 7A MICROSTRUCTURE OF CONTAINMENT SHELL PLATE SHOWING FERRITE AND PEARLITE

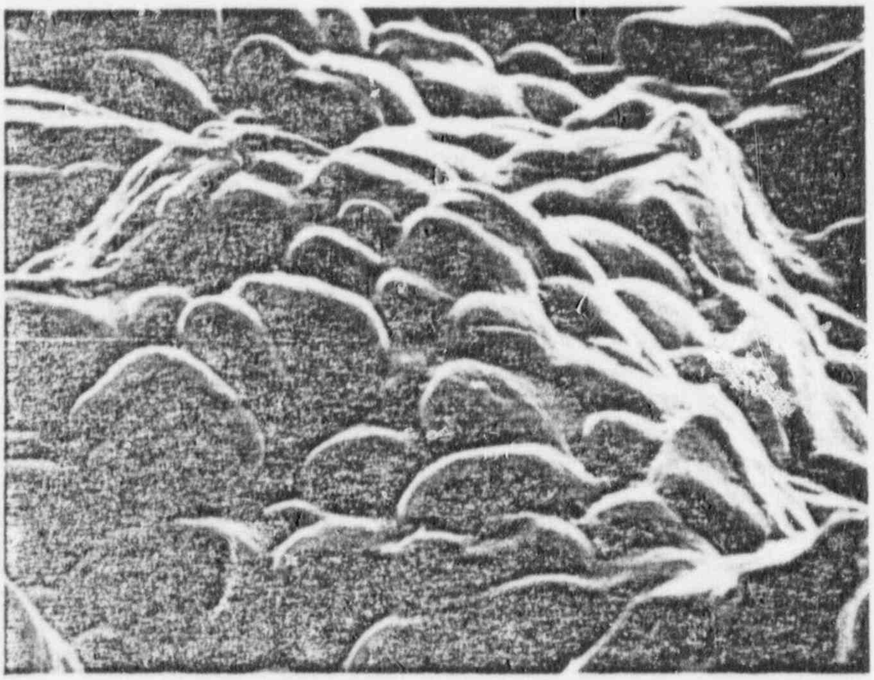
MAG. 500x
ETCHANT-2% NITAL

FIGURE 7B MICROSTRUCTURE OF EMBEDMENT PLATE SHOWING FERRITE AND PEARLITE ORIENTED ALONG ROLLING DIRECTIONS



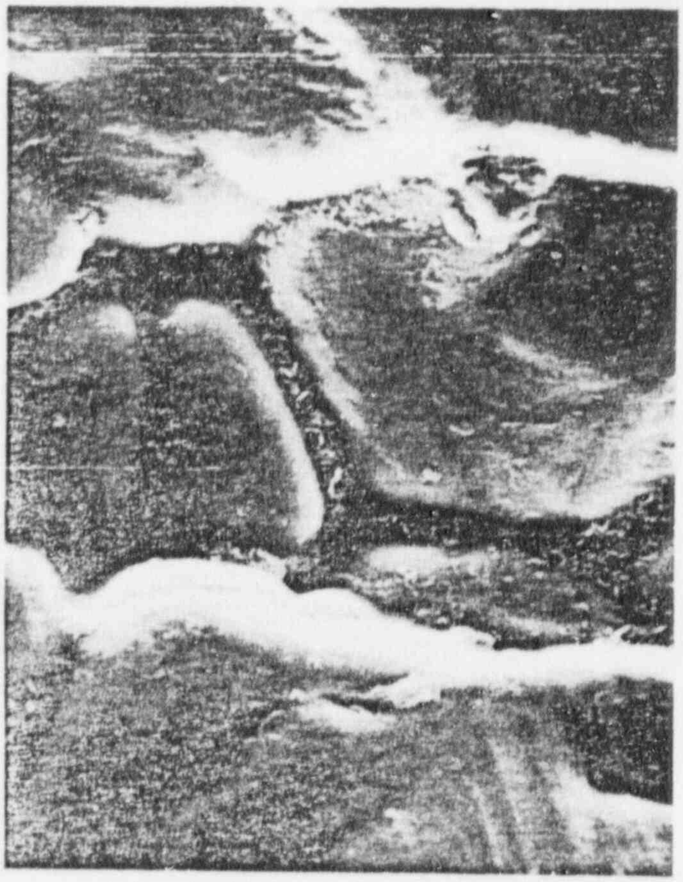
MAG. 3.5x

FIGURE 8   PHOTOGRAPH OF DEFECT SURFACE



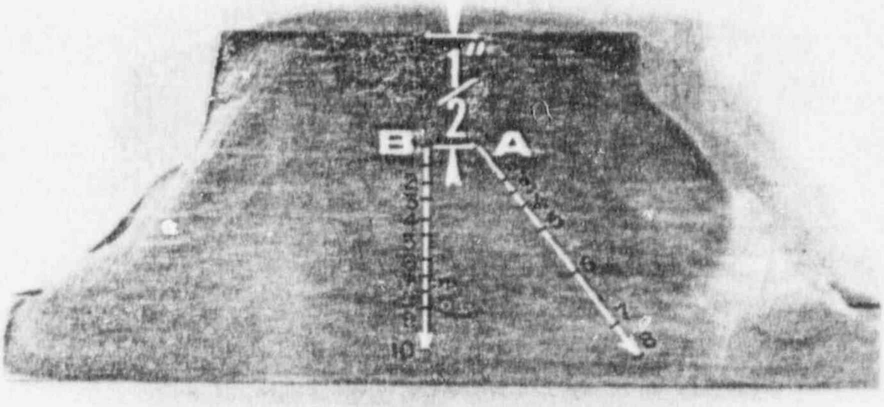
MAG. 1100x

FIGURE 9 INTERDENDRITIC STRUCTURE OF THE DEFECT SURFACE UNDER SCANNING ELECTRON MICROSCOPE



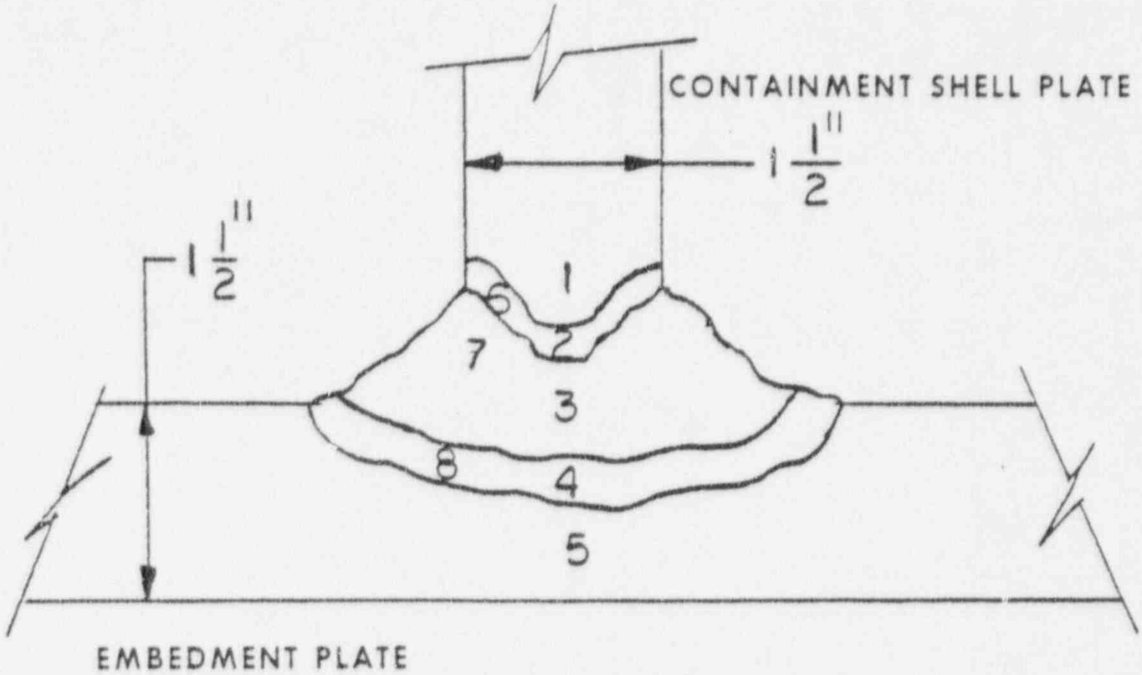
MAG. 2750x

FIGURE 10 DEFECT SURFACE SHOWN IN FIGURE 9 AT HIGHER MAGNIFICATION, SHOWING DENDRITIC GRAINS



MAG. 1.5x

FIGURE 11 PHOTOGRAPH OF THE SPECIMEN SHOWING LOCATIONS OF MICROHARDNESS TESTS



LOCATION NO.	IDENTIFICATION
1	BASE METAL - CONTAINMENT SHELL PLATE
2	HAZ - ABOVE SAW LARGE BEAD
3	WELD METAL - SAW LARGE BEAD
4	HAZ - BELOW SAW LARGE BEAD
5	BASE METAL - EMBEDMENT PLATE
6	HAZ - AWAY FROM ROOT IN SHELL PLATE
7	WELD METAL - AWAY FROM ROOT PLATE
8	HAZ - AWAY FROM ROOT IN EMBEDMENT PLATE

FIGURE 12 SKETCH IDENTIFYING LOCATIONS OF CHARPY V-NOTCH TEST SPECIMENS

TABLE 1

RESULTS OF MICROHARDNESS TESTS

	Location Scan A	Hardness Rockwell B Scale	Hardness Vickers No.
1	Base Metal	63.5	114
2	HAZ	92.5	207
3	HAZ	98.0	241
4	Weld Metal	100.5	258
5	Weld Metal	99.5	249
6	Weld Metal	94.5	219
7	HAZ	102.5	271
8	Base Metal	94.0	216
	Scan B		
1	Base Metal	88.0	184
2	HAZ	92.0	204
3	HAZ	100.5	258
4	Weld Metal	97.0	234
5	Weld Metal near Defect	96.5	230
6	Weld Metal	97.0	234
7	Weld Metal (SMAW)	91.0	198
8	HAZ	103.5	280
9	HAZ	96.0	230
10	Base Metal	90.0	195

TABLE 2

RESULTS OF CHARPY IMPACT TESTS

Location	Temperature 0°F Energy in ft/lbs	Temperature 0°F Average	Temperature 40°F Energy in ft/lbs	Temperature 40°F Average
1	47.5 34.0 35.6	39.0	-	
2	27.0 21.5 16.5	21.7	28.5 23.0 30.0	27.1
3	26.5 37.5 59.0	41.0		
4	15.5 10.0 18.0	14.5	23.3 25.8 29.5	26.2
5	23.0 18.0 12.0	17.7	38.0 39.0 43.0	40.0
6	14.0 18.5 20.0	17.5	51.0 45.8 61.0	52.6
7	50.0 57.0 57.5	54.8		
8	57.0 32.3 32.0	40.4*		

*Specimen orientation caused notch to extend in weld metal.

TABLE 3

RESULTS OF CHEMICAL ANALYSIS

Location of Sample	C	Mn	Si	S	P	Ni	Cr	Mo
Weld Metal at an near crack	0.13	1.33	0.19	0.010	0.005	0.091	0.052	0.19
Weld Metal away from crack	0.09	1.48	0.17	0.013	0.005	0.072	0.047	0.37
Embedment Plate	0.22	0.63	0.22	0.009	0.005	0.13	0.06	0.07
Containment Shell Plate	0.24	1.00	0.18	0.019	0.005	0.18	0.09	0.04

C - Carbon

Mn - Manganese

Si - Silicon

S - Sulfur

P - Phosphorus

Ni - Nickel

Cr - Chromium

Mo - Molybdenum

ATTACHMENT 1

Graver Energy Systems
Welding Procedure Specification 302N

RIVER BEND STATION - UNIT 2
GULF STATES UTILITIES
WEST FELICIANA PARISH, LA.
J.O. No. [redacted]-12330 - P.O. No. 219-710-C056

GRAVER TANK & MFG. CO.

DATE: 10/14/76

ORDER NO. 61060N

ATTACHMENT 1

WELDING PROCEDURE SPECIFICATION NO: 302N

REVISIONS: Rev. 1- 10-14-76
Rev. 2- 9-1-77

SUPPORTING P.Q.R. NUMBERS: S-118B

JOINTS

Groove Design: Double Bevel Groove Welds

Backing: None

Other:

FILLER MATERIAL

	SMAW		SAW
F No.	4	Other	---
A No.	1	Other	---
Spec. No.	5.1 (SFA)		--- (AWS)
Class	E7018		Linde #40
Electrode Size	5/32" dia.		1/8" dia.

Electrode/Flux Composition: Lincoln 860 Flux- F-72 Linde #40 ~~Mil-E-18193A~~

Other: Type Mil-B4

BASE METAL

P No. 1 Group No. 2

to

P No. 1 Group No. 2

Thickness Range: 5/8" - 1-1/2"

Other: Weld Bead, Thickness not to exceed 1/2"

POSTWELD HEAT TREATMENT

____ Yes X No

Temperature

Time

PREHEAT X YES ___ NO

Preheat Temperature > 1" -200°F
≤ 1" -100°F

Interpass Temperature 350°F

Preheat Maintenance None

Other

ELECTRICAL CHARACTERISTICS

Current DC (AC-DC)

Polarity Reverse

Amps (range): SMAW 140-185, SAW 400-650

Volts (range): SMAW 20-24, SAW 26-33

Travel Speed 10-20 IPm

Other

POSITION

Position of Groove Horizontal (2F)

Progression

Other

Stone & Webster Engineering Corporation
☒ APPROVED AS DEFINED IN THE SPECIFICATIONS
☐ UNACCEPTABLE
☐ APPROVED AS REVISED AS DEFINED IN THE SPEC.
☐ REVIEWED
J.O. No. N/A/2330
SPEC. No. 218.715
DATE 9/14/77
BY G. Ramchandran

GRAVER TANK & MFG. CO.

PROCEDURE SPECIFICATION NUMBER: 302N

TECHNIQUE	GAS
String or Weave Bead: String	Shielding Gas: N/A
Initial & Interpass Cleaning: Deslag, Grind or Power Brush	Flow Rate: N/A
Method of Back Gouge: Arc Air Goug or Grind	Purge or Backing: N/A
Multipass or Single: Multiple side	Other:
Multiple or Single Electrode: Multiple	SKETCH: See Attached Sketch Sheet No. 610B680
Cup Size: N/A	
Contact Tube to Work: 3/4" - 1-1/4"	
Retainer used - None Elec. spacing - 1/2" to 2".	

REMARKS: The welding shall be done using single mounted welding heads, operating independently on either or both sides of the weld joint.

Rev. 1 Requalified in the horizontal position using multiple electrode

Rev. 2 9-1-77 Corrected electrode type.

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code 1974 Edition.

GRAVER TANK & MFG. COMPANY
An Aerojet-General Company

BY C. K[illegible]

DATE Oct. 15, 1976

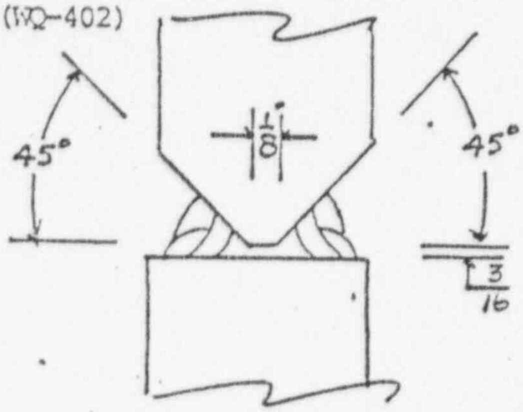
PROCEDURE QUALIFICATION RECORD | DATE: 10-14-76

PROCEDURE QUALIFICATION RECORD NUMBER: S-118B | WPS NUMBER: 302N

BRAVER TANK & MFG. CO.

WELDING PROCESS(ES): SMAW/SAW | TYPES: Manual and Automatic

JOINTS (WQ-402)



BASE METAL (QW-403)
Material Spec. SA516
Type or Grade 70
P No. 1 Group 2 to P No. 1 Group 2
Thickness 1-1/4"
Diameter --
Other

FILLER METALS (QW-404) — SAW / SMAW
Weld Metal Analysis A No. -- / 1
Size of Electrode 1/8"Ø / 5/32"Ø
Filler Metal F. No. -- / 4
SFA Specification -- / 5.1
AWS Classification -- / E7018
Other Linde #40, Type Mil-B4
Mil-E-18193-A
Lincoln 860 Flux-F-72

POSITION (QW-405)
Position of Groove Horizontal (2G)
Weld Progression N/A
(Uphill, Downhill)
Other

PREHEAT (QW-406)
Preheat Temperature 200°F
Interpass Temperature 350° MAX
Other

POSTWELD HEAT TREATMENT (QW-407)
Temperature None
Time
Other

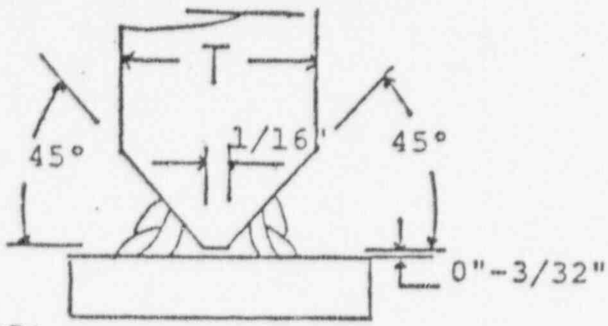
GAS (QW-408)
Type of Gas or Gases N/A
Composition of Gas Mixture
Other

ELECTRICAL CHARACTERISTICS (QW-409)
Current DC
Polarity Reverse
Amps SMAW / SAW 140-185, 400, 650 Volts SMAW / SAW 20-24, 26-33
Travel Speed 10-20 IPM
Other

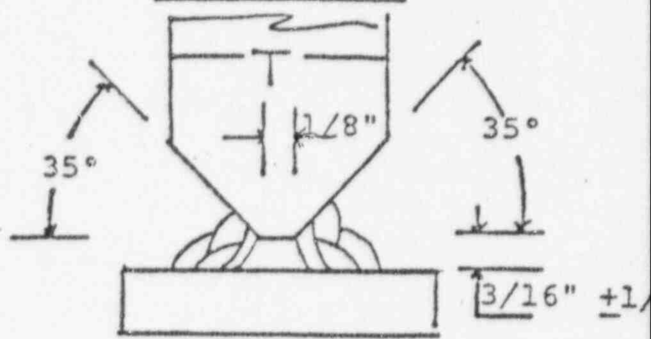
TECHNIQUE (QW-410)
String or Weave Bead String
Oscillation N/A
Single or Multiple Electrodes Multiple (2)
Other 1. Shielded metal arc root pass not to exceed two (2) passes
3. Weld bead thickenss not to excee 1/2 inch. 4. Elec. spacing - 1/2 to 2"

ORDER NO.	REV.	DATE	REVISION DESCRIPTION Page 4 of 5
DRAWING NO: 610B680	1	10/14/76	Requalified in the hor. posit using multiple electrodes
DATE:	2	9-1-77	Corrected electrode type
GRAVER TANK & MFG. CO.	3		
	4		
SPECIFICATION NO. 302N	5		

T-5/8" - 1-3/16" max.



T->1-3/16" - 1-1/2"



Notes:
1. Lincoln 860 Flux
2. Linde No. 40 Wire
3. Nose ± 1/16"

	First Welded Side (Lead Elec)					Second Welded Side (Trail Elec)					
T	Fillet Size	Pass No.	Elec. Dia.	Volts	Current	Fillet Size	Elec Dia.	Pass No.	Volts	Current	Speed I.P.M
5/8"	3/8"	1-2	1/8"	26-29	400-500	3/8"	1/8"	1-2	26-29	400-500	10-14
		3-4		26-29	400-500			3-4	26-29	400-500	16-20
1"	3/8"	1-2	1/8"	26-29	400-500	3/8"	1/8"	1-2	26-29	400-500	10-14
		3-5		26-29	400-500			4-5	26-29	400-500	16-20
1-1/4*	5/8"	1	5/32"	22-24	140-175						
		2	1/8"	26-29	450-525	5/8"	1/8"	2	26-29	500-550	10-16
		3-6	1/8"	29-29	450-550		1/8"	3-12	26-29	450-550	16-20
1-1/2*	5/8"	1	5/32"	22-24	140-175						
		2	1/8"	26-29	450-525	5/8"	1/8"	2	26-29	500-550	10-16
		3-12	1/8"	26-29	450-550		1/8"	3-12	26-29	450-550	16-20

Notes:
1. Maximum Interpass Temperature 350°
2. Number of fill pass may vary due to fabrication and fit-up.
3. Manual root pass shall be made with E7018, 5/32" dia. elec.
4. The reverse side of the root pass shall be arc air gouged or ground to remove excessive weld metal and cleaned by wire brushing.

PROCEDURE QUALIFICATION RECORD

TENSILE TEST (QW-150)

SPECIMEN NO.	WIDTH	THICKNESS	AREA	ULTIMATE TOTAL LOAD LB.	ULTIMATE UNIT STRESS PSI	CHARACTER OF FAILURE & LOCATION
1	.755	1.527	1.152	95,000	82,400	Base Metal
6	.780	1.530	1.193	97,500	81,700	Base Metal HAZ
						—

GUIDED BEND TESTS (QW-160)

TYPE AND FIGURE NO.	RESULT	TYPE AND FIGURE NO.	RESULT
QW462.2(A)2	Satisfactory	QW462.2(A)3	Satisfactory
QW462.2(A)4	Satisfactory	QW462.2(A)5	Satisfactory

TOUGHNESS TESTS (QW-170)

SPECIMEN NO.	NOTCH LOCATION	NOTCH TYPE	TEST TEMP	IMPACT VALUES	LATERAL EXP. % SHEAR	LATERAL EXP. MILS	DROP WEIGHT BREAK	DROP WEIGHT NO BREAK
1	CW	Vee	-35	28	25%	29		
2	CW	Vee	-35	38	30%	41		
3	CW	Vee	-35	30	30%	31		
1	HAZ	Vee	-35	40	35%	42		
2	HAZ	Vee	-35	43	40%	45		
3	HAZ	Vee	-35	36	35%	37		

Type of Test ______

OTHER ______

FILLET WELD TEST (QW-180)

Result - Satisfactory N/A (yes, No) Penetration into Parent Metal ______ (yes, No)

Type & Character of Failure ______ Macro-Results ______

Welder's Name R. Leadingham Clock No. 1022 Stamp No. Oval 5

Tests Conducted by Graver & M.R.L. Lab Test No. S 118 B

per T. Michniewicz

We certify that the statements in this record are correct and that the tests welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code 1974 Edition.

Signed C Kelley

Date 10-14-76 By Oct. 15, 1976

GRAVER TANK & MFG. CO.